

OPTIMIZATION OF GRINDING PARAMETER WHEN GRIND HAYNES 242 USING
WATER BASED TITANIUM OXIDE (TiO₂) NANOCOOLANT

SANGEETHA A/P GOVINDASAMY

Report submitted in partial fulfilment of the requirements for the award of the degree of
Bachelor of Mechanical Engineering with Manufacturing Engineering

Faculty of Mechanical Engineering
UNIVERSITI MALAYSIA PAHANG

JUNE 2012

ABSTRACT

This thesis entitled Optimization of Grinding Parameter when grind Haynes 242 using water based Titanium Oxide (TiO_2) Nanocoolant. The objective of this thesis is to find optimum parameter which is the Depth of cut. The thesis also is to investigate type of surface roughness and wheel wear produced during grinding process. Haynes 242 material was used as the work piece and Titanium Oxide as Nanocoolant was used for this grinding process. The another objective of this thesis is also to develop prediction model for surface roughness and wheel wear produced using Neural Network Analysis. These studies will be done for two experimental processes which is the single pass and multi pass experiment according to different depth of cut. As result, we observed that as the depth of cut increases, the surface roughness of the material also increases. However, when compare between the single pass and multi pass experiment, we can observed that surface roughness for single pass are much higher than the multi pass experiment. As for the recommendation, in future we can conduct the experiment using different kind of concentration, various depths of cut, different passes and also different types of material.

ABSTRAK

Tesis ini yang bertajuk Pengoptimuman Parameter Pengisar apabila mengisar Haynes 242 menggunakan Titanium Oksida (TiO_2) cecair Nano. Objektif tesis ini adalah untuk mencari parameter optimum iaitu Kedalaman pemotongan. Tesis ini juga adalah untuk menyiasat jenis kekasaran permukaan dan kehausan roda yang dihasilkan semasa proses pengisaran. Haynes 242 adalah bahan yang telah digunakan sebagai bahan kerja dan Oksida Titanium, sebagai cecair Nano digunakan untuk proses pengisaran. Objektif lain tesis ini juga adalah untuk mengembangkan model ramalan untuk kekasaran permukaan dan pemakaian roda yang dihasilkan menggunakan Artificial Neural Network. Kajian-kajian ini akan dijalankan untuk dua proses eksperimen yang pas tunggal dan pelbagai pas mengikut perbezaan kedalaman potongan. Hasilnya, kami memerhatikan bahawa apabila kedalaman pemotongan menaik, kekasaran permukaan bahan juga meningkat. Walau bagaimanapun, apabila bandingkan antara pas tunggal dan pas berbilang, kita boleh memerhatikan bahawa kekasaran permukaan untuk pas tunggal adalah lebih tinggi daripada eksperimen pas berbilang. Bagi syor itu, pada masa akan datang kita boleh menjalankan eksperimen menggunakan pelbagai jenis kaedah, pelbagai kedalaman potongan, pelbagai pas berlainan dan juga pelbagai jenis bahan.

TABLE OF CONTENTS

	Page
EXAMINER APPROVAL	ii
SUPERVISOR’S DECLARATION	iii
STUDENT’S DECLARATION	iv
DEDICATION	v
ACKNOWLEDGEMENTS	vi
ABSTRACT	vii
ABSTRAK	viii
TABLE OF CONTENTS	ix
LIST OF TABLES	xii
LIST OF FIGURES	xiii
LIST OF SYMBOLS	xiv
LIST OF ABBREVIATIONS	xv

CHAPTER 1 INTRODUCTION

1.1	Background of Study	1
1.2	Problem Statements	2
1.3	Objectives	2
1.4	Scopes of Study	2
1.5	Thesis Outline	3

CHAPTER 2 LITERATURE REVIEW

2.1	Introduction	4
2.2	Grinding Machining Process	4
	2.2.1 Surface Grinding Machine	5
	2.2.2 Types of Surface Grinding	6
2.3	Grinding Parameter	7
	2.3.1 Depth of Cut	7
2.4	Material of Work piece	7
2.5	Nanocoolant	10
	2.5.1 Size matters in Nanocoolant	10

	2.5.2 Making Nanocoolant	11
	2.5.3 Characterizing Nanocoolant	12
	2.5.4 Application of Nanocoolant	12
2.6	Titanium Oxide	13
	2.6.1 Thermal Conductivity	14
	2.6.2 Viscosity	17
	2.6.3 Neural Network	18

CHAPTER 3 METHODOLOGY

3.1	Introduction	20
3.2	Design of Experiment	20
	3.2.1 Wheel Properties	20
	3.2.2 Grinding Machine Specification	21
	3.2.3 Preparation of Nanocoolant	22
	3.2.3.1 Preparation of Nanocoolant New Tank	23
	3.2.3.2 Preparation of Distilled Water	23
	3.2.3.3 Calculation of Titanium Oxide Concentration	24
	3.2.3.4 Dilution Process	25
	3.2.3.5 Nanocoolant Prepared	28
3.3	Properties of TiO ₂ Nanocoolant	29
3.4	Experimental Setup	32
	3.4.1 Nanocoolant setup	32
	3.4.2 Grinding Process	32

CHAPTER 4 RESULTS AND DISCUSSION

4.1	Introduction	36
4.2	Surface Roughness Measurement	36
	4.2.1 Microstructure Observation	40
4.3	Wheel Wear	43
4.4	Neural Network	44
	4.4.1 Single Pass	44
	4.4.2 Multi Pass	5

CHAPTER 5 CONCLUSION AND RECOMMENDATIONS

5.1	Introduction	51
5.2	Conclusions	51
5.3	Future Recommendations	52
REFERENCES		53

LIST OF TABLES

Table No.		Page
2.1	Chemical Composition of Haynes 242	8
2.2	Typical room temperature physical properties	9
2.3	Comparison of thermal conductivity enhancement in TiO ₂	15
3.1	Specification of Supertech Grinding Machine	22
3.2	Concentration of Titanium Oxide in Weight and Volume Percentage	24
3.3	Example of Actual Versus Output table	34
4.1	Surface roughness obtained for single pass	38
4.2	Surface roughness obtained for multi pass	38
4.3	Wheel wear result for single pass	43
4.4	Wheel wear result for multi pass	44
4.5	Target and Output Result obtain using neural network	44
4.6	Summary (single pass)	45
4.7	Prediction of surface roughness (single pass)	46
4.8	Target and Output Result obtain using neural network	47
4.9	Summary (Multi Pass)	48
4.10	Prediction of surface roughness (Multi Pass)	48

LIST OF FIGURES

Figure No	Title	Page
2.1	Surface Grinding Machine	5
2.2	Transmission electron micrograph	9
2.3	Experimental results of relative thermal conductivity of TiO ₂	16
2.4	Experimental data for the relative thermal conductivity of TiO ₂	17
3.1	Silicon Carbide Wheel	21
3.2	Supertech Surface Grinding Machine	22
3.3	Aquamatic Water Still	23
3.4	Distilled Water Prepared	24
3.5	Dilution Process	26
3.6	Titanium Oxide Nanocoolant Prepared	28
3.7	KD2 image	30
3.8	KD2 Pro transient hotwire thermal conductivity meter	30
3.9	Variation of property enhancement ratio temperature for TiO ₂	31
3.10	Nanocoolant pipe fixing	32
3.11	Setting grinding machine	34
3.12	Wheel Dressing	35
4.1	Surface Roughness for multi pass and single pass	38
4.2	Comparison of surface roughness for TiO ₂ and water based coolant	40
4.3	Roughness for single pass	41
4.4	Roughness for multi pass	42
4.5	Graph of Actual result versus Output result	45

4.6	Graph of Actual result versus Output result	47
4.7	Surface roughness for single pass and multi pass for prediction	50

LIST OF SYMBOLS

ω	Natural frequency
V	Volume
μm	Micrometer
Δ	Difference in volume
$^{\circ}\text{C}$	Celsius
$^{\circ}\text{F}$	Fahrenheit
K	Kelvin

LIST OF ABBREVIATIONS

Ra	Surface Roughness
TiO ₂	Titanium Oxide
Ni	Nickel
Mo	Molybdenum
Cr	Chromium

Mn	Manganese
Si	Silicon
Al	Aluminium
C	Carbon
B	Boron
Cu	Copper
EG	Ethylene Glycol
TEM	Transmission Electron Microscopy
PWR	Pressurized Water Reactors
RPM	Revolution per Minute
H ₂ O	Water
Al ₂ O ₃	Aluminium Oxide
CuO	Copper Oxide
ANN	Artificial Neural Network
SiC	Silicon Carbide

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

The grinding process is a wide, large and diverse area of manufacturing and tool making. This grinding process normally placed at the end of a production line for finishing parts with an excellent and fine surface finish and also to produce products with high dimensional accuracy. The most significant impact on the overall yield and productivity of the entire production line is obtained via the result and productivity of the grinding operation. Improvement of productivity and reduction in cost for the grinding process is increasing significantly through advanced optimization and control. However, the grinding process remains one of the most difficult to control manufacturing processes due to its nonlinear, complex and time varying nature. Determining desirable operating parameters and the tools of the grinding process in an industrial environment is predicated on operator experience and also by trial and errors method which often results in inconsistency in part qualities and low productivity. Grinding parameter which is the depth of cut should be optimized when doing the grinding process. This project is to optimize the grinding parameter of Haynes 242 material using water based Titanium Oxide nanocoolant. Besides, this study also is to investigate the type of surface roughness and wear produced during experimental process (Cheol W. Lee, 2000)

1.2 PROBLEM STATEMENT

Haynes 242 alloy is an age hardenable nickel-molybdenum chromium alloy which derives its strength from a long-range ordering reaction upon aging. Haynes 242 used commonly in industry because of its characteristic that combines high temperature strength, low thermal expansion and good oxidation. Different types of parameter in grinding process will give effect to the characteristic of the work piece. In this research, the grinding operation carried out to optimize the parameters to produce fine surface roughness and tool wear. The parameter used in this grinding process is depth of cut. Nanocoolant works better in term of thermal, so using nanocoolant will give better results for the grinding process.

1.3 OBJECTIVES

The objectives of this project are:-

- a) To find optimum parameter which is the depth of cut
- b) To investigate type of surface roughness and wear produced during grinding process
- c) To develop prediction model for surface roughness and wheel wear produced using Neural Network

1.4 SCOPE/LIMITATION

In order to achieve the objectives notified earlier, the following scopes have been identified:-

- a) Preparation of Titanium Oxide water based nanocoolant for grinding process
- b) Conduct experiment using silicon carbide wheel.
- c) Conduct grinding process for single pass (9 exp) and multi pass (9 exp).
- d) To obtain prediction model for surface roughness and wheel wear produced using Neural Network.

- e) Use Perthometer to measure Surface Roughness and Tachometer to control work Speed (200 rpm)
- f) Use different depth of cut (5,7,9,11,13,15,17,19,21) μm for the grinding process.

1.5 THESIS OUTLINE

This thesis consists of five chapters. Chapter 1 gives the introduction of this project. In this introduction part, there will be brief explanations about the background of this study, the problem statement, the objective of this study, and the scope/limitation in this project. This chapter is as a fundamental for the project and act as a guidelines for project research completion.

Chapter 2 discuss about the literature review of this project. Literature review will be mainly discussed on the Grinding machining process, Surface Machining Process, Material of work piece, Nanocoolant Properties, Titanium Oxide Nanocoolant and Thermal Conductivity of TiO_2

Chapter 3 describes the methodology part of the study. Methodology gives information about the design of experiment, experimental setup, equipment used for the grinding process and process flow of the experiment.

Chapter 4 discuss about the result and discussion part of the study. The result for surface roughness and wheel wear produced will be analyzed. Hence, the objective of this project will be achieved in this chapter.

Chapter 5 will give the overall conclusion of the project. The conclusion made will be based on the experiment and result analysis. Recommendation will be provided based on the experience during the grinding process.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter is discussing on some literatures review which related to the optimization of grinding parameter of Haynes 242 using water based Titanium Oxide Nanocoolant. Literature review will be mainly discussed on the Grinding machining process, Material of work piece, Nanocoolant Properties, Titanium Oxide Nanocoolant and Thermal Conductivity of TiO_2

2.2 GRINDING MACHINING PROCESS

Grinding is an abrasive machining process which uses a grinding wheel as a cutting tool for finishing process. There are many types of grinding operation in Grinding machining process such as Surface grinding, Cylindrical grinding, Centerless grinding, Creep-feed grinding, Electrochemical grinding and also other grinding processes. In this research, Surface Grinding will be used for this machining process. Surface grinding is used to produce an excellent and smooth finish on flat surfaces. It is a widely used abrasive machining process in which a spinning wheel covered in rough particles (grinding wheel) cuts chips of metallic or non metallic substance from a work piece, making a face of it flat or smooth (P. Krajniet.al, 1999)

2.2.1 Surface Grinding Machine

Surface grinding is the most common of the grinding operations. It is a finishing process that uses a rotating abrasive wheel function to smooth the flat surface of metallic or nonmetallic materials to give them a more refined look or to attain a desired surface for a functional purpose. The surface grinder is composed of an abrasive wheel, a work holding device known as a chuck and a reciprocating table. The chuck holds the material in place while it is being worked on. The metallic pieces are held in place by a magnetic chuck, while nonmetallic pieces are vacuumed in place. Factors to consider in surface grinding are the material of the grinding wheel and the material of the piece being worked on. The grinding wheel is not limited to just a cylindrical shape, but can have a myriad of options that are useful in transferring different designs to the object being worked on (P. Krajnik et al, 1999)



Figure 2.1: Surface Grinding Machine

Source: Grinding Lab, University Malaysia Pahang

2.2.2 Types Of Surface Grinding

a) Horizontal-spindle (peripheral) surface grinders

The periphery (flat edge) of the wheel is in contact with the work piece, producing the flat surface. Peripheral grinding is used in high-precision work on simple flat surfaces, tapers or angled surfaces, slots, flat surfaces next to shoulders recessed surfaces and profiles. (Rogelio et al, 2003)

b) Vertical-spindle (wheel-face) grinders

The face of a wheel (cup, cylinder, disc, or segmental wheel) is used on the flat surface. Wheel-face grinding is often used for fast material removal, but some machines can accomplish high-precision work. Indexing allows loading or unloading one station while grinding operations are being performed on another. The work piece is held on a reciprocating table, which can be varied according to the task or a rotary-table machine with continuous or indexed rotation. (Rogelio et al, 2003)

c) Disc grinders and double-disc grinders

Disc grinding is similar to surface grinding but with a larger contact area between disc and work piece. Disc grinders are available in both vertical and horizontal spindle types. Double disc grinders work both sides of a work piece simultaneously. Disc grinders are capable of achieving especially fine tolerances (Rogelio et al, 2003)

2.3 GRINDING PARAMETER

The relevant variable for the grinding process is the cutting parameter (depth of cut) work piece geometry (initial surface texture and form errors) wheel topography and vibration (Y. Wang et al, 1998). Grinding parameter used in this study is Depth of cut.

2.3.1 Depth of Cut

Depth of cut refers to the distance of the grinding wheel penetrates into the work piece. When the cutting depth is big, the work speed becomes faster and thus increases the surface temperature. The surface roughness of the work piece also will be changed (Kwak J.S., 2004)

2.4 MATERIAL OF WORKPIECE

Haynes 242 alloy is an age hardenable nickel-molybdenum chromium alloy which derives its strength from a long-range ordering reaction upon aging. It has tensile and creep strength properties up to 1300⁰F (705⁰C) which are as much as double those for solid solution strengthened alloys but with high ductility in the aged condition. Haynes 242 alloy exhibits significantly lower thermal expansion characteristics than most nickel-base high temperature alloys in the range of temperature from room temperature to 1600⁰F (870⁰C) and it has very good oxidation resistance up to 1500⁰F (815⁰C).

Haynes 242 alloy has very good forming and welding characteristics in the annealed condition. It may be forged or otherwise hot-worked by conventional techniques and it is readily cold formable. Haynes 242 alloy is furnished in the annealed condition, unless otherwise specified. The alloy is usually annealed in the range of 1900-2050⁰F (925-1120⁰C) depending upon specific requirements, followed by an air cool (or more rapid cooling) before aging (Haynes International, Inc)

Haynes 242 alloy is produced in the form of reforge billet, bar, plate, sheet, and wire welding products in all various sizes. Haynes 242 alloy combines properties which make it ideally suited for a variety of component applications in the aerospace industry. It will be used for seal rings, containment rings, duct segments, casings, fasteners, rocket nozzles, pumps and many others (M.K. Miller et.al)

In the chemical process industry, 242 alloys will find use in high-temperature hydrofluoric acid vapour containing processes as a consequence of its excellent resistance to that environment. The alloy also displays excellent resistance to high temperature fluoride salt mixtures. The high strength and fluorine environment resistance of 242 alloys has also been shown to provide for excellent service in fluoroelastomer process equipment, such as extrusion screws. Table 2.1 shows the chemical composition of Haynes 242 (Stephen D. Antolovich, 2000)

Table 2.1: Chemical Composition (%) of Haynes 242

Chemical Composition (%) of Haynes 242	
Ni	65.0
Mo	25.0
Cr	8.0
Fe	2.0
Co	2.5
Mn	0.8
Si	0.8
Al	0.5
C	0.03
B	0.006
Cu	0.5

Haynes 242 alloy derives its age-hardened strength from a unique long range ordering reaction which essentially doubles the un-aged strength while preserving excellent 2000 by Haynes International, Inc. ductility. The ordered $\text{Ni}_2(\text{Mo}, \text{Cr})$ -type domains are less than a few hundred Angstroms in size, and are visible only with the use of electron microscopy (Haynes International. Inc)



Figure 2.2: Transmission electron micrograph showing long-range-ordered (dark lenticular particles) in 242 alloys

Source: Dr. Vijay Vasudevan, University of Cincinnati

Table 2.2: Typical room temperature physical properties

	British Units	Metric Units
Density	0.327 lb/in ³	9.06 g/cm ³
Electricity Resistivity	48.0 μ ohm-in	122.0 μ ohm-cm
Dynamic modulus of Elasticity	33.2 x 10 ⁶ psi	229 Gpa
Thermal Conductivity	75.7 Btu-in/ft ² -hr-°F	11.3 W/m-K
Specific Heat	0.092 Btu/lb.-°F	386 J/Kg-K

2.4 NANOCOOLANT

Nanocoolant can be considered to be the next-generation heat transfer fluids as they offer exciting new possibilities to enhance heat transfer performance compared to pure liquids. They are expected to have superior properties compared to conventional heat transfer fluids, as well as fluids containing micro-sized metallic particles. The much larger relative surface area of nanoparticles, compared to those of conventional particles, should not only significantly improve heat transfer capabilities but also should increase the stability of the suspensions.

Moreover, nanocoolants can improve abrasion-related properties as compared to the conventional fluid mixtures. Successful employment of nanocoolants will support the current trend toward component miniaturization by enabling the design of smaller and lighter heat exchanger systems. Koblinski et al made an interesting simple review to discuss the properties of nanocoolants and future challenges. The development of nanocoolants is still hindered by several factors such as the lack of agreement between results, poor characterization of suspensions, and the lack of theoretical understanding of the mechanisms. Nanocoolant are produced by dispersing nanometer-scale solid particles into base liquids such as water, ethylene glycol (EG) and oils (Stephen U. S. Choi, 2000)

2.5.1 Size Matters in Nanocoolant

Before diving into the specifics of the thermal properties of nanotechnology-based HTFs, it is important to understand the importance of particle size in creating practical nanocoolants. First of all, particle size matters in making nanocoolants stable. Dense nanoparticles can be suspended in liquids because the particles have an extremely high ratio of surface area to volume so that the interaction of the particle surface with the liquids is strong enough to overcome differences in density example the gravity effect is negligible. Furthermore, nanoparticles are charged and thus particle interactions are not allowed. Second, size matters in making nanocoolants with novel properties. The very

small particle size can affect transport mechanisms at the nanoscale. The properties of nanocoolants are dominated not only by the characteristics of nanoscale surface or interface structures but also by nanoscale dynamics (Stephen U. S. Choi, 2000)

2.5.2 Making Nanocoolants

Dispersing the nanoparticles uniformly and suspending them stably in the host liquid is critical in producing high-quality nanocoolants. Good dispersion and stable suspension are prerequisites for the study of nanocoolants properties and for applications. The key in producing extremely stable nanocoolants is to disperse mono sized nanoparticles before they agglomerate. Many two-step and one-step physical and chemical processes have been developed for making nanocoolants. These processes can be summarized as follows:-

- *Two-step process*

In a typical two-step process, nanoparticles, nanotubes, or nanofibers are first produced as a dry powder by physical or chemical methods such as inert gas condensation and chemical vapour deposition. This step is followed by powder dispersion in the liquid. The major problem with two-step processes is aggregation of nanoparticles. Kwak, K. and Kim, C, 2005 showed that particles, strongly aggregated before dispersion, are still in an aggregated state after dispersion in ethylene glycol. Most researchers purchase nanoparticles in powder form and mix them with the base fluid.

However, these nanocoolants are not stable, although stability can be enhanced with pH control and/or surfactant addition. Some researchers purchase commercially available nanocoolants. But these nanocoolants contain impurities and nanoparticles whose size is different from vendor specifications. Although the two-step process works fairly well for oxide nanoparticles, it is not as effective for metallic nanoparticles (A.K. Singh)

- *One-step process*

In a one-step process, synthesis and dispersion of nanoparticles into the fluid take place simultaneously. For example, Argonne developed a one-step nanocoolant production system in which nanoscale vapour from metallic source material can be directly dispersed into low vapour pressure fluids (A.K. Singh)

2.5.3 Characterizing Nanocoolants

Good methods for characterizing nanocoolants are critical to a correct understanding of their novel properties. Characterization of nanocoolants includes determination of colloidal stability, particle size and size distribution, concentration, and elemental composition as well as measurements of thermophysical properties. For some applications, measurement of the electrical conductivity of nanocoolants is required. Some of the most commonly used tools for characterization include transmission electron microscopy (TEM) imaging and dynamic light scattering (DLS). One of the most measured thermophysical properties is the thermal conductivity of nanocoolants. Generally, three methods are used to measure the thermal conductivity of nanocoolants such as the transient hot wire method, 3- ω method and the laser flash method (Stephen U. S. Choi)

2.5.4 Applications of Nanocoolants

Nanocoolants can be used in a wide range of applications wherever improved heat transfer or efficient heat dissipation is required. Major examples include electronics, automotive, and nuclear applications. The following examples give a picture of the versatility of this technology. Nanocoolants are a promising candidate for microelectronics cooling. Tsai et al used gold nanocoolants as the working fluid for meshed circular heat pipe. Their results show that, at the same charge volume, there is a significant reduction (by as much as 37%) in the thermal resistance of the heat pipe with a nanocoolant as compared with de-ionized water (A.K. Singh)

Nanocoolants have a plethora of potential applications in many automotive parts and functions, including engine coolant, automatic transmission fluid, power steering fluid, fan clutches, engine oil, power electronics, brake fluid, gear lubrication, and greases. The first commercial steps of nanocoolants technology have been made in the automobile arena. Tzeng et al. are the first to apply nanocoolants in cooling a real-world automatic power transmission system. Nuclear applications of nanocoolants appear to be very promising or perhaps the most promising of currently envisaged uses (A.K.Singh)

Nanocoolants could be used in primary systems, emergency safety systems, and severe accident management systems, with resulting benefits such as power upgrades in commercial pressurized water reactors (PWR) and enhanced safety margins during design-basis events and severe accidents. In general, nanocoolants could enhance economics and safety of nuclear reactors. They also have great potential as a coolant for safer and smaller nuclear generators in the future. Beyond these somewhat concrete possibilities lies a broad expanse of potential applications, wide open to the engineering imagination (A.K. Singh)

2.6 TITANIUM OXIDE (TiO₂)

Titanium Oxide is a widely used white pigment because of its brightness. It can also oxidize oxygen or organic materials, therefore, it is added to paints, cements, windows, tiles, or other products for sterilizing, deodorizing and anti-fouling properties and when incorporated into outdoor building materials can substantially reduce concentrations of airborne pollutants. Additionally, as TiO₂ is exposed to UV light, it becomes increasingly hydrophilic (attractive to water), thus it can be used for anti-fogging coatings or self cleaning windows.

Titanium (v) Oxide water based nanocoolant used in this project is the mixture of Rutile and Anatese which contain <150nm particle size dispersion, 33-37 wt% in H₂O, 99.9% frace metal basis.